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Bird use of short rotation coppice strips within a modern silvoarable agroforestry system during the winter season: comparison of different coppice strip variants and hedgerows

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Abstract

Silvoarable agroforestry systems (AFS) with short rotation coppice strips (CS) are considered to be a potential measure to promote biodiversity in agricultural landscapes while simultaneously producing arable crops and woody biomass. However, there are few studies that examine the actual potential of these novel land-use systems to enhance biodiversity. Therefore, in this study, the use of three different variants of CS (“Conventional” [CS-C], “Aspen“ [CS-A], and “Ecological“ [CS-E]) by birds during the winter season was investigated within an experimental AFS site in northern Germany. In addition, surveys in hedgerows in the immediate vicinity were conducted to compare the habitat function and quality of these woody habitats of traditional AFS with CS (representing elements of modern AFS). Bird surveys were made by point counts on eight dates between November 2021 and February 2022, with each section surveyed for exactly 10 minutes per visit. In addition, the food supply of seed- and fruit-bearing woody plants within the variant “CS-E“ (where native woody species were planted with the aim of an ecological improvement in addition to high-yielding poplar clones) and within the hedgerows was assessed. Overall, hedgerows had the highest species numbers and the most birds were observed there. In fact even more species were recorded and more birds were observed in the hedgerows (16 species, 195 bird observations) than in all three CS variants together (13 species, 136 observations, thereof 12 species and 116 observations in CS-A, 5 species and 16 observations in CS-E, and 3 species and 4 observations in CS-C). In the CS sections, no birds were detected on a majority of the visits (77–95%), while in hedgerows birds were detected on 83% of the visits. On the individual recording dates, significantly more species were detected and more birds were observed in the hedgerows than in CS-C and CS-E on each of the eight dates. By contrast, hedgerows and CS-A differed significantly (hedgerows with more species and bird observations) on only three out of eight dates. Among the three CS variants, CS-A had the most species and bird detections overall, though there were no significant differences between the three variants on any of the eight recording dates. With regard to the food supply associated with the woody plants, an equal number of woody species was found in the CS-E and hedgerow sections. However, the number of woody species actually bearing seeds and fruits, and the number of trees/shrubs carrying seeds and fruits, were significantly higher in the hedgerow sections. Thus, the plant-based food supply offered by the hedgerows was much greater and more diverse. Overall, the results show that hedgerows are more important (foraging) habitats for birds in the winter season than CS. The surprisingly poor performance of the CS-E variant was probably caused by the fact that the native woody species were harvested for the last time one year before the study and are usually harvested at short intervals (3–6 years), which explains the limited presence of seed- and fruit-bearing trees and shrubs despite the planting of various native woody species. Thus the native woody species in CS-E should be harvested much less frequently so that this variant achieves greater importance as foraging habitat for birds. The clear preference for hedgerows over CS, and their much more diverse and extensive food supply even at the end of the survey period, together with the (currently) low use of CS-E, indicate that there was a sufficient supply of seed- and fruit-bearing trees and shrubs in the surrounding landscape and that the integration of CS and the planting of native woody species in CS-E therefore added only limited value. Modern silvoarable AFS with CS are therefore likely to be more important in cleared agricultural landscapes that lack higher-quality woody habitats such as hedgerows or groves. Thereby the additional cultivation of native, seed- and fruit-bearing woody species in short rotation or for the production of timber could further increase the food supply and structural diversity of the CS.

Keywords: biodiversity, species richness, alley cropping, perennial biomass crop, bioenergy

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Introduction

Silvoarable agroforestry systems (AFS) with short rotation coppice strips (CS) are novel land use systems, in which strips of fast-growing trees such as poplar (*Populus* spp.) or willow (*Salix* spp.) are established between croplands, so that a simultaneous production of woody biomass and arable crops takes place (Böhm et al. 2014, Nerlich et al. 2013). In contrast to traditional AFS, for example agricultural land divided by hedgerows, modern AFS are adapted to current (mechanised) agricultural production methods and high-yielding varieties of woody species are cultivated (Nerlich et al. 2013).

In addition to their production capacity, modern AFS can provide further ecosystem services. For example, the woody strips can reduce soil erosion by wind (Böhm et al. 2014) and contribute to climate protection through carbon sequestration (Peichl et al. 2006, Wolz et al. 2018), and the reduction of N_2O emissions (due to the substantial use extensification within the tree rows compared with arable monocultures without tree rows; Beaudette et al. 2010, Shao et al. 2023). Furthermore, AFS with CS are considered as a possible tool to counteract the decline of structural diversity in agricultural landscapes, and thus contribute to the promotion of biodiversity (Glemnitz et al. 2013, Nerlich et al. 2013, Porter et al. 2009, Quinkenstein et al. 2009, Tsonkova et al. 2012). Currently, however, AFS with CS are not particularly widespread either in Europe or in Germany (Beer and Theuvsen 2019, Tsonkova et al. 2018) and cultivation is almost exclusively limited to experimental sites (Otter and Beer 2021). Therefore there is still a lack of knowledge on the actual potential of these novel land use systems to promote biodiversity in agricultural landscapes (Boinot et al. 2022, Mupepele et al. 2021, Tsonkova et al. 2012).

With regard to avifauna, there are some studies on breeding birds that show that the integration of CS on cleared arable land creates habitats for common tree- and shrub-breeding species (Glemnitz et al. 2013, Löffler et al. 2016), but the habitat quality clearly lags behind that of hedgerows, *i.e.* woody structures of traditional AFS (Zitzmann and Langhof 2023). By contrast, there are no studies on the use of CS by birds in the winter season, although birds in intensively managed agricultural landscapes are confronted with a considerable lack of food and cover during this time (a.o. Geiger et al. 2010, Siriwardena et al. 2008) and the integration of CS on arable land might create new foraging habitats and cover opportunities (*cf.* Fry and Slater 2011 and Sage et al. 2006 for short-rotation coppice plantations).

The aim of this study is therefore to determine the use of CS by birds in the winter season. Thereby, three different variants of CS on an experimental site in northern Germany were investigated and compared with regard to their utilisation by birds. In addition, comparisons of the habitat function of these CS variants with hedgerows are made, as hedgerows are the counterpart to CS within traditional AFS (*cf.* Nerlich et al. 2013) and are considered to be important habitats for wintering birds in agricultural landscapes (Hinsley and Bellamy 2000).

Materials and methods

Study sites. The investigation was carried out on an AFS experimental site (coordinates: 52°19′54.7“N 10°37′52.8“E) in the municipality of Lehre (district of Helmstedt, Niedersachsen, Germany). The site, with a total area of 17.7 ha, was established in 2008 and consists of nine short-rotation coppice strips (CS) and cropland between them (Fig. 1). The CS each have a length of 225 m and a width of 10 m. Each of the nine CS consists of three 75-m-long sections representing different CS variants: "Conventional" (CS-C), "Aspen" (CS-A), and "Ecological" (CS-E):

- **CS-C** consists of six poplar rows (planting scheme 2 x 0.5 m) with three different fast-growing poplar clones: "Koreana" (*P. koreana* x *P. trichocarpa*), "Max 1" (*P. nigra* L. x *P. maximowiczii*), and "Hybride 275" (P. *maximowiczii* x *P. trichocarpa*) in equal proportions. This variant is intended for full use in short rotation (harvesting every 3 to 6 years) and represents the conventional use option for CS.
- **CS-A** consists of four rows of poplars analogous to CS-C, but in contrast to CS-C two poplar rows in the middle were replaced by a row of aspen *Populus tremula*, which were planted with a distance of 1.5 m between the trees; they are are used for timber production.
- **CS-E** also consists of four rows of poplars analogous to CS-C, but with the addition of two rows of native tree and shrub species (such as *Prunus spinosa*, *Malus sylvestris*, *Rosa canina*, *Viburnum opulus*, *Sambucus nigra*, *Cornus sanguinea*, *Crataegus monogyna*, *Sorbus aucuparia*, *Ligustrum vulgare*) that were planted on the windward side in order to enhance the habitat function by providing diverse woody structures offering additional habitats and a provision of fruits and flowers for wildlife.

The poplar clones in all CS, and the native woody species in the CS-E sections, were last harvested in January 2021. Poplar clones and native woody species thus were present as one-year-old regrowth during the bird surveys in the winter season 2021/2022 and had an average height of 3.5 m (poplar clones) and 2 m (native woody species in CS-E). Aspen in CS-A have not been

Fig. 1. View of the AFS experimental site (bordered in red) with the different CS variants (bordered in white; C = Conventional, A = Aspen, and E = Ecological) and the eight hedgerow sections (yellow, each 75 m long). Each CS is 225 m long and consists of three 75-m-long sections of the different variants. Background: Orthophoto taken by the State Office for Geoinformation and Land Surveying of Lower Saxony on 24 March 2022. – *Agroforst-Versuchsfläche (rot umrandet) mit den verschiedenen Varianten von Kurzumtriebsstreifen (weiß umrandet; C = Konventionell, A = Aspen und E = Ökologisch) und die acht Heckenabschnitte (gelb, jeweils 75 m lang). Die Kurzumtriebsstreifen sind insgesamt 225 m lang und bestehen aus drei jeweils 75 m langen Abschnitten der verschiedenen Varianten.*

harvested since their establishment and were about 15 m high. Eight of the total nine CS within the AFS were included in the study, as harvesting of the aspen row in one CS-A section meant that this section differed considerably from the other eight sections of this variant and was therefore no longer suitable for comparison.

In addition to the eight CS, eight hedgerows were included as reference habitats. They were located in the immediate vicinity of the AFS at a distance of max. 400 m (Figure 1). For the hedgerows, 75-m sections were examined, analogous to the length of the CS sections of the respective variants. Only hedgerows characterised by a shrub-like structure or by trees no taller than 15 m, which did not contain mature trees, were considered, in order to achieve a fair comparability with the CS. The surveyed hedgerows had a width of between 5.2 m and 8 m and were between 7 m and 15 m high.

Survey methods, data preparation, and data analysis. Winter birds were surveyed using point counts (*cf.* Bibby et al. 2000, Fischer et al. 2005). A total of eight recording dates were carried out between mid-November 2021 and mid-February 2022. Per section (n = 8 per type, each 75 m long) the recording time per date was exactly 10 minutes. Therefore the recording time per section was 80 minutes over the entire survey period. With eight sections per type, this results in a total recording time of 10 hours and 40 minutes per habitat type (*i.e.* CS-C, CS-A, CS-E, and hedgerows). The position for the observations was centrally located at a distance of about 30 m from the surveyed CS or hedgerow section. Using binoculars, the 75-m sections of the CS or hedgerows were scanned for birds and all visually and acoustically perceptible bird species detected in the respective section within the survey time of 10 minutes were noted. In addition, it was noted how many individuals of each species were present in the surveyed section during this time. To avoid double counts, only the maximum number of individuals of a species simultaneously present within the respective section was counted, so no summation of the observed individuals over the 10 minutes of recording time was made. All sections were surveyed on the same day between 9 am and 3 pm. On the individual dates, the surveys were started at different sections in order to examine them at different times of day. Surveys were only conducted in good weather conditions, hence not in heavy rain or snowfall and without strong winds.

The prerequisites for using parametric tests were not given due to a lack of normal distribution (tested with Shapiro-Wilk test) and homogeneity of variance (tested with Levene's test). Thus the winter bird surveys data (*i.e.* species numbers and number of bird observations per recording date and over all dates) were tested for significant differences between the four habitat types (three CS variants and hedgerows) using the non-parametric Kruskal-Wallis test and Dunn's test with Bonferroni correction as post-hoc test. Statistical analysis was performed in R, version 4.3.1 (R Core Team 2023), using package "rstatix" (version 0.7.2; Kassambara 2023).

The following must be considered regarding the choice of the statistical test for the analysis of the bird data. Although the same number of sections (n = 8) per habitat type was studied and all sections had the same length (75 m), the width of the habitat types differed: hedgerows were between 5.2 and 8 m wide, while all sections of the CS variants were 10 m wide. Nevertheless, width could not be included in the statistical analyses because it varied only among the hedgerows but was uniform among the CS. Thus it was not possible to include width as a co-variable or offset variable in the analyses because it was directly and inseparably related to habitat type. In addition, a preliminary analysis of the hedgerow data (generalised linear model, Poisson/quasipoisson distribution assumption, hedgerow width as regressor) in R did not reveal any correlation between the width of the surveyed hedgerow sections and the respective number of species and bird observations recorded. Therefore based on these data, an effect of width on the numbers of species and bird observations within the hedgerows could not be proven empirically. Thus it was not possible to assume a fixed, proportional relationship between width and counts (species, bird observations) and to include it in the analyses via offset variable (*i.e.* an extrapolation of species and observation counts to a uniform width of 10 m in the context of the statistical analysis). For these reasons width was not included in the analyses but instead the Kruskal-Wallis test was used as a robust statistical test for non-parametric data.

In addition to the bird surveys, the food supply of seeds and fruits associated with the woody plants was recorded in the CS-E variant and in the hedgerows. In the two other CS variants (CS-C, CS-A) no survey was carried out, as only different species or clones of the genus *Populus* were planted there, which do not provide any food in winter due to their early seed dispersal (for spring and summer *cf.* Braatne et al. 1996 and Guilloy-Froget et al. 2002). To quantify the food supply of the woody plants within CS-E and the hedgerows, the number of tree and shrub species present in each section (n = 8 sections per type) was determined. In addition, the number of woody species and the number of their individuals actually bearing fruits or seeds were recorded in each section on two dates: at the beginning of the bird surveys in November and at the end in February. Some woody plants were recorded only at the genus level because identification to species was not possible or too difficult in the winter season (especially for *Crataegus* and *Rosa* species), or because identification to species level was not relevant with regard to the food supply (for *Populus* and *Salix* species, whose seed maturation and dispersal ends already in summer). The two habitat types were compared with regard to the recorded variables using the Mann-Whitney-*U*-test in R, version 4.3.1 (R Core Team 2023).

Results

Bird counts. A total of 20 species was detected and 331 bird observations were made across all habitat types and recording dates (Tab. 1). Most birds were found in the eight reference hedgerow sections, with a total of 16 species and 195 observations, followed by CS-A with 12 species and 116 observations. CS-E (5 species, 16 observations) and CS-C (3 species, 4 observations) had considerably fewer species and fewer observations. If all three CS variants (24 sections, 1800 m total length) are combined then with 13 species and 136 observations fewer species were recorded and fewer observations were made than in the eight hedgerow sections (600 m total length). Within the three CS variants, moreover, no bird detections were made on a majority of the survey dates (77–95% of a total of 64 visits per variant), while birds were detected on a majority of the survey dates within the hedgerows (Tab. 1).

Most observations were made of Fieldfare (27.8% of all observations), Great Tit (21.8%), Blue Tit (16.9%), and Goldfinch (7.6%). Fieldfare mostly occurred in larger flocks (up to 27 birds), but on only a few dates. Great Tit and Blue Tit, on the other hand, were recorded on many dates but with few observations per date, whereby the majority of observations were made in the hedgerow sections and both species were only rarely recorded within the CS. Of all species found, only Yellowhammer and Great Tit were detected across all four habitat types; all other species were absent from at least one habitat type. Several species were observed only once, *i.e.* on a given date in a single section of a given habitat type (*e.g.* Great Spotted Woodpecker, Marsh Tit, or Magpie).

Hedgerows had the highest number of species per section on each of the eight recording dates and differed significantly from CS-C and CS-E on all dates (Tab. 2). Compared to CS-A, however, the number of species per section only differed significantly on three dates, while no significant differences were found on five dates. The three CS variants did not differ on any of the eight recording dates with regard to the number of species found per section. The total number of detected species per section (sum of detected species considering all eight recording dates) was also highest in the hedgerows and differed significantly from CS-C and CS-E; however, despite a mean value more than twice as high, there was no significant difference from CS-A. There were no significant differences between the three CS variants with regard to this variable either.

With regard to the number of bird observations (Tab. 2), the results are almost the same as for the number of species. Again, hedgerows had a significantly higher number of observations than CS-C and CS-E on each of the eight recording dates (except for date 1, where no difference between hedgerows and CS-E was found), while there were no differences between the three CS variants. Compared to CS-A, however, the number of observations per section differed significantly on only three dates, while no significant differences between hedgerows and CS-A were found on five dates. The total number of observations per section (sum of bird observations considering all recording dates) was also highest in the hedgerows and these differed significantly from CS-C and CS-E, but not from CS-A.

As the values in Tabs. 1 and 2 indicate, especially in CS-C and CS-E, but also in CS-A, there was a high number of survey dates with no bird detections (77–95% per variant) or, in some cases in CS-A and the hedgerows, also detections of larger flocks of birds on individual recording dates and in individual sections. The high number of null observations and individual high values explain the high standard deviation from the mean value in Table 2 and the non-significant differences between the CS variants (and in some cases also between CS-A and hedgerows) despite clear differences in the mean value.

Food supply of the woody species. In CS-E and hedgerows, a similar number of woody species ($p = 0.483$) were found per section (Tab. 3). Across all eight sections, however, the hedgerows were far more species-rich. A total of 22 woody species were recorded here, while only 13 species were found in CS-E. The number of woody species that actually carried seeds or fruits was significantly higher in the hedgerow sections than in the CS-E sections in both November ($p = 0.0009$) and February ($p = 0.009$). Similarly, the number of individual trees/shrubs bearing seeds or fruits per section was significantly higher in the hedgerows at both dates: in November ($p = 0.0007$) the number in the hedgerows was

Tab. 1. Bird species detected and species-specific number of observations across all recording dates and sections of the respective habitat type (8 sections each 75 m in length per type, 8 recording dates, each with 10 min. recording time, per section = 600 m total length per type and 64 visits or 10 h and 40 min. total recording time per type), sorted in descending order of total number of observations. CS = Short rotation coppice strip variants: C = Conventional, A = Aspen and E = Ecological. HR = Hedgerows (reference habitat). – *Nachgewiesene Vogelarten und Anzahl der artspezifischen Beobachtungen unter Berücksichtigung aller Erfassungstermine und Abschnitte der jew. Habitattypen (8 Abschnitte von je 75 m Länge pro Typ, 8 Termine (mit je 10 Min. Erfassungszeit) pro Abschnitt = 600 m Gesamtlänge pro Typ und 64 Erfassungstermine bzw. insgesamt 10 h und 40 Min. Erfassungszeit pro Typ), sortiert nach der Gesamtanzahl der artspezifischen Beobachtungen. CS = Kurzumtriebsstreifen in den Varianten C = Konventionell, A = Aspen und E = Ökologisch. HR = Hecken (Referenzlebensraum).*

Species name	**CS-C**	**CS-A**	**CS-E**	**HR**	**Total**
Fieldfare *Turdus pilaris*		67		25	92
Great Tit *Parus major*	1	3	6	62	72
Blue Tit *Cyanistes caeruleus*		1	3	52	56
Goldfinch *Carduelis carduelis*		23		2	25
Blackbird *Turdus merula*				15	15
Bullfinch *Pyrrhula pyrrhula*			3	12	15
Yellowhammer *Emberiza citrinella*	2	9	1	3	15
Robin *Erithacus rubecula*				10	10
Tree Sparrow *Passer montanus*		3	3		6
Common Kestrel *Falco tinnunculus*		3		2	5
Eurasian Jay *Garrulus glandarius*				4	4
Chaffinch *Fringilla coelebs*				3	3
Greenfinch *Chloris chloris*		2		1	3
Carrion Crow *Corvus corone*	1	1		1	3
Common Buzzard *Buteo buteo*		2			2
Corn Bunting *Emberiza calandra*		1			1
Marsh Tit *Poecile palustris*				1	1
Wren *Troglodytes troglodytes*				1	1
G. Sp. Woodpecker *Dendrocopos major*		1			1
Eurasian Magpie *Pica pica*				1	1
Total no. of species	3	12	5	16	20
Total no. of bird observations	4	116	16	195	331
Bird observations per minute	0.006	0.181	0.025	0.305	0.129
Visits with bird detections	3	15	7	53	
(n = 64 visits per variant)	(5%)	(23%)	(11%)	(83%)	–

on average almost nine times higher, and in February ($p = 0.0016$) about five times higher than in CS-E. Across all eight sections and both survey dates, 13 woody species bearing seeds and fruits were found in the hedgerows compared to only three species (*Ligustrum vulgare*, *Rosa* spec. and *Rubus caesius*) in CS-E.

Discussion

An unsurprising result of the study is the comparatively poor performance of CS-C. In this variant only poplar clones were present, which do not provide any seed supply for birds during the winter season due to the early dispersal of their seeds (*cf.* Braatne et al. 1996, Guilloy-Froget et al. 2002), leading to a rather low importance of this variant as a foraging habitat for birds in the winter season (*cf.* Reddersen et al. 2001 for short rotation coppice plantations). Accordingly, however, it would have been expected that CS-A would perform similarly to CS-C, since only trees of the genus *Populus* were planted here as well, and that CS-E would perform best among the three CS variants due to its greater woody species diversity. Contrary to this expectation, overall

Tab. 2. Mean number of bird species ± SD and mean number of bird observations ± SD per recording date and section ($n = 8$ sections per type) and mean number of species and observations ± SD per section across all recording dates. Comparisons between habitat types were made by Kruskal-Wallis test followed by Dunn's post-hoc test. Values with no consistent letter indicate significant differences ($p<0.05$). * $p<0.05$, ** $p<0.01$, *** $p<0.001$. CS = Short rotation coppice strip variants: C = Conventional, A = Aspen and E = Ecological. HR = Hedgerows. – *Mittelwert* ± SD *der Anzahl nachgewiesener Vogelarten und der Anzahl an Vogelbeobachtungen pro Erfassungstermin und Abschnitt (n = 8 Abschnitte pro Habitattyp) und pro Abschnitt über alle Erfassungstermine hinweg. Vergleiche zwischen den Habitattypen erfolgten mit dem Kruskal-Wallis-Test und dem Dunn-Test als Post-hoc-Test. Werte mit unterschiedlichen Buchstaben unterscheiden sich signifikant (p<0.05). * p<0.05, ** p<0.01, *** p<0.001. CS = Kurzumtriebsstreifen in den Varianten C = Konventionell, A = Aspen und E = Ökologisch. HR = Hecken.*

Date	Variable	CS-C	CS-A	CS-E	HR	*p*
1	Species	0 ± 0 [a]	0.4 ± 1.1 [ab]	0.3 ± 0.7 [a]	1.5 ± 1.6 [b]	**
	Observations	0 ± 0 [a]	1.8 ± 4.9 [ab]	0.8 ± 2.1 [ab]	2.6 ± 2.8 [b]	**
2	Species	0 ± 0 [a]	0.8 ± 1.4 [ab]	0.1 ± 0.4 [a]	1.4 ± 0.9 [b]	**
	Observations	0 ± 0 [a]	2.1 ± 4.9 [ab]	0.1 ± 0.4 [a]	1.9 ± 1.5 [b]	**
3	Species	0 ± 0 [a]	0.6 ± 0.9 [ab]	0 ± 0 [a]	0.9 ± 0.6 [b]	**
	Observations	0 ± 0 [a]	1.1 ± 2.1 [ab]	0 ± 0 [a]	1.1 ± 1.0 [b]	**
4	Species	0.1 ± 0.4 [a]	0.4 ± 1.1 [a]	0.3 ± 0.5 [a]	2.1 ± 1.2 [b]	**
	Observations	0.1 ± 0.4 [a]	1.5 ± 4.2 [a]	0.8 ± 1.4 [a]	4.4 ± 3.1 [b]	**
5	Species	0 ± 0 [a]	0.6 ± 0.7 [ab]	0.1 ± 0.4 [a]	1.8 ± 0.7 [b]	***
	Observations	0 ± 0 [a]	5.1 ± 10.0 [ab]	0.1 ± 0.4 [a]	3.3 ± 2.1 [b]	***
6	Species	0 ± 0 [a]	0.3 ± 0.5 [ab]	0.1 ± 0.4 [a]	1.5 ± 1.1 [b]	**
	Observations	0 ± 0 [a]	1.8 ± 4.2 [ab]	0.1 ± 0.4 [a]	1.9 ± 1.6 [b]	**
7	Species	0.1 ± 0.4 [a]	0.1 ± 0.4 [a]	0.1 ± 0.4 [a]	1.5 ± 0.9 [b]	***
	Observations	0.3 ± 0.7 [a]	1.0 ± 2.8 [a]	0.1 ± 0.4 [a]	2.1 ± 1.0 [b]	**
8	Species	0.1 ± 0.4 [a]	0.1 ± 0.4 [a]	0 ± 0 [a]	2.1 ± 1.5 [b]	***
	Observations	0.1 ± 0.4 [a]	0.1 ± 0.4 [a]	0 ± 0 [a]	7.1 ± 10.3 [b]	***
Total no. per section	Species	0.4 ± 0.5 [a]	2.4 ± 3.0 [ab]	0.9 ± 0.8 [a]	5.8 ± 1.8 [b]	***
	Observations	0.5 ± 0.8 [a]	14.5 ± 20.5 [ab]	2.0 ± 2.4 [a]	24.4 ± 10.6 [b]	**

considerably more species and individuals were found in CS-A than in the other CS variants (Table 1), although differences between the CS variants were not significant on all recording dates (Table 2). The fact that CS-A did better than CS-E despite a lower woody species diversity seems surprising at first glance. However, it was noticeable that birds of prey (Kestrel, Buzzard) and larger flocks of Fieldfare and Goldfinch (both species accounted for >75% of the total bird observations in CS-A) exclusively used the CS-A sections within the AFS, which explains the comparatively high total number of species and total number of bird observations. The greater use of this variant was presumably caused by the fact that the approx. 15-m-high aspen trees were the highest point within the AFS and therefore served as a hunting perch for birds of prey, or were used for short resting periods by passing flocks. Therefore, the main reason for the better performance of CS-A is probably the large structural difference from the other CS variants and not the food supply. Thus, CS-A did not primarily serve as a foraging habitat for most species, but rather, due to the height of the trees, primarily served as a short-term resting place and perch for hunting in adjacent fields.

The surprisingly poor performance of the CS-E variant, on the other hand, is not only unfortunate from a bird conservation point of view, but also from a financial perspective. This variant achieves lower wood yields, since two rows of fast-growing and high-yielding poplar clones were replaced by native woody species. Moreover, the cost of their purchase and planting is higher than that of poplar cuttings (*cf.* Schildbach et al. 2009). Thus the higher costs and lower yields, at least at the time of the study, have not been offset by any enhancement effect for winter birds compared to the conventional variant (CS-C). The limited use of CS-E by birds suggests that the food supply of the native tree and shrub species with seeds and fruits, and presumably also the supply of arthropods as a food resource (see below), was currently not sufficient to significantly improve the habitat quality for winter birds compared to the other CS variants, and in particular compared to the hedgerows studied. This is also highlighted by the results of the survey of seed- and fruit-bearing woody plants: Although the same number of woody species per section was found in CS-E as in the hedgerows, only a few of these species, and also only a few individual trees/shrubs, actually carried seeds and fruits (Tab. 3). This shows that the food supply of the woody plants in the hedgerows was much greater, both in quality and quantity. CS-E was harvested one year before the study, and the native tree and shrub species were in a regrowth stage with a comparatively lower growth volume than before harvesting. Without harvesting the native woody plants one year before, CS-E would probably have been more important for birds in the winter season. However, it remains open if and to what extent the attractiveness of CS-E will increase in subsequent years as the native woody species continue to regrow and continue to age, and whether it will then

Tab. 3. Mean number of woody species ± SD and mean number of trees/shrubs (individuals) ± SD per CS-E or hedgerow (HR) section ($n = 8$ sections per type). Comparisons between the two habitat types were made by Mann-Whitney-*U*-Test. Significantly greater values ($p<0.05$) are marked in bold. – *Mittelwert ± SD erfasster Gehölzarten, Samen oder Früchte tragender Gehölzarten und Samen oder Früchte tragender Gehölze (also einzelne Bäume oder Sträucher) pro Abschnitt (n = 8 Abschnitte pro Habitattyp) in CS-E und Hecken (HR). Der Vergleich der Habitattypen erfolgte mit dem Mann-Whitney-U-Test. Signifikant höhere Werte (p<0.05) sind fett hervorgehoben.*

	CS-E	**HR**
No. of woody species	11.1 ± 0.8	10.8 ± 2.3
November		
No. of seed or fruit-bearing woody species	1.9 ± 0.6	**4.9 ± 1.7**
No. of seed or fruit-bearing trees/shrubs	5.8 ± 2.4	**54.1 ± 17.8**
February		
No. of seed or fruit-bearing woody species	1.3 ± 0.7	**3.3 ± 1.5**
No. of seed or fruit-bearing trees/shrubs	3.1 ± 1.7	**15.8 ± 11.2**

achieve the intended enhancement effects for birds in winter compared to the other CS variants. Most likely, the current practice of harvesting CS-E at short intervals (3–6 years) has a negative effect on the food supply and habitat quality for winter birds, as only little regrowth can occur in the short time until the next harvest, especially when harvesting at 3-year intervals. Therefore, it might be more beneficial to harvest the native woody species in CS-E less frequently than the poplar clones. This would leave structures for cover and foraging after the poplars have been harvested. In addition, suitable nesting opportunities for shrub-breeding birds would remain in the breeding season after harvesting (Zitzmann and Langhof 2023), and the rows with native woody species could serve as protection against wind erosion (*cf.* Böhm et al. 2014).

Another aspect that needs to be considered regarding the food supply offered by the investigated habitat types is their provision of arthropod prey in and on the ground as well as on the woody plants. This was not recorded in the field as part of the study in the winter season 2021/2022. However, surveys within the present AFS conducted in winter 2012 show that more species and a higher biomass of arthropods were found in soil samples from surrounding semi-natural habitats, such as hedgerows or forest edges, than in the CS (Dauber et al. 2016). Accordingly, and in line with the literature, it is assumed that hedgerows provide a considerably larger and more diverse food supply for insectivorous birds than the surveyed CS variants due to their greater woody species richness (especially in comparison to CS-C and CS-A), their greater structural diversity, their reduced harvest-related disturbance, and their higher age (of both the woody plants and the stands themselves) (cf. Arnold 1983, Dauber et al. 2018, Froidevaux et al. 2019, Maudsley 2000, Pfiffner and Luka 2000, Pollard and Holland 2006; see also Ampoorter et al. 2020 for the positive influence of tree diversity on biodiversity in forests and Schulz et al. 2008 on the habitat potential of willows and poplars in short rotation coppice plantations for insects in comparison to the habitat potential of these tree species at other locations). Thus the greater importance of the studied hedgerows for birds in the winter season is probably not exclusively related to their greater supply of seeds and fruits, but presumably also to their greater and more diverse supply of arthropods. However, whether the arthropod food supply increases with the further ageing of the crops, and as a result of the less frequent harvesting of the native woody species in CS-E, and how the different CS variants perform in comparison to hedgerows, should be further investigated. This should consider arthropods within and on the soil and on the woody plants as well as different seasons (breeding season, winter season).

With regard to seed- and fruit-bearing trees and shrubs, it should also be noted that even at the end of the study (mid-February) the surveyed hedgerows still offered a significantly greater and more diverse food supply than CS-E (Tab. 3). This indicates that there was apparently a sufficient provision of seed- and fruit-bearing woody plants in the surveyed landscape and that most bird species were therefore not dependent on the food supply offered by CS-E. Moreover, in CS-E only three woody species provided fruits at all. In the hedgerows, on the other hand, considerably more species (13) carried seeds and fruits, so that the requirements of different frugivorous species were met there with regard to their winter food preference (*cf.* Stiebel and Bairlein 2008), which (in combination with the presumably higher diversity and abundance of arthropods) explains the considerably higher numbers of bird species and observations and the clear preference of hedgerows over CS-E. The high importance of the surveyed hedgerows is also underlined by the fact that there were more species recorded and more birds observed than in all three CS variants together. This suggests that the costly integration of native woody species in CS (as CS-E variant) to promote birds in the winter season might be particularly useful in landscapes with a low supply of woody habitats such as hedgerows or groves, as the importance of CS and especially the CS-E variant (especially if the native woody plants are harvested at longer intervals) is then likely to be significantly higher than in the landscape studied here due to the lack of high-quality foraging habitats. When establishing modern silvoarable AFS in cleared and structurally impoverished agricultural landscapes, it would then also be possible to cultivate further tree species in the CS that are suitable for use as short-rotation crops. In addition to poplars and willows this includes, for example, alders (*Alnus* spp.), birches (*Betula* spp.) or rowans (Veste et al. 2018). Besides benefits for birds (increased structural diversity and food supply), the cultivation of different woody species can also result in economic advantages, as the risk of total failure is significantly reduced compared to the planting of a single clone or species/clones of the same genus (Böhm and Veste 2018, Coyle et al. 2005). In addition, a higher woody species diversity within CS would also promote insect diversity, as different insect species are associated with different tree genera and species (Brändle and Brandl 2001, Kennedy and Southwood 1984, Schulz et al. 2009) or even varieties (Müller et al. 2018). This in turn directly benefits insectivores, e.g. many bird species during the breeding season, but also during the winter season (Ampoorter et al. 2020, Arnold 1983). If trees with longer rotation periods are to be grown for timber production in combination with fast-growing trees for bioenergy use, such as aspen in the example of CS-A, other slower growing tree species could be used for this purpose as well (Morhart et al. 2010), which could further increase structural diversity and food supply for birds or other animals of higher trophic levels in modern AFS. Conceivable species include wild cherry *Prunus avium*, wild service tree *Sorbus torminalis*, persian walnut *Juglans regia* or European crab apple *Malus sylvestris* (Nerlich et al. 2013).

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Zusammenfassung

Winterliche Nutzung von Kurzumtriebsstreifen innerhalb eines modernen silvoarablen Agroforstsystems durch Vögel: Vergleich verschiedener Varianten von Kurzumtriebsstreifen und Hecken.

Silvoarable Agroforstsysteme (AFS) mit Kurzumtriebsstreifen (CS) werden als mögliche Maßnahme angesehen, einen Beitrag zur Förderung der Biodiversität in Agrarlandschaften zu leisten und gleichzeitig Feldfrüchte und Holz zu produzieren. Bisher gibt es jedoch kaum Studien, die das tatsächliche Potenzial dieser neuartigen Nutzungssysteme zur Förderung der Biodiversität untersuchen. Daher wurde im Rahmen dieser Arbeit die Nutzung von drei Varianten von CS („Konventionell“ (CS-C), „Aspen“ (CS-A) und „Ökologisch“ (CS-E)) durch Vögel im Winterhalbjahr innerhalb einer AFS-Versuchsfläche in Norddeutschland untersucht. Zusätzlich erfolgten Erfassungen in Hecken im unmittelbaren Umfeld der Versuchsfläche, um die Habitatfunktion und -qualität dieser Gehölzstrukturen traditioneller AFS mit den CS (als Gehölzstrukturen moderner AFS) zu vergleichen. Die Vogelerfassungen erfolgten mittels Punktzählungen an acht Terminen zwischen November 2021 und Februar 2022, wobei jeder Abschnitt von CS und Hecken pro Termin jeweils exakt 10 Minuten beobachtet wurde. Zusätzlich erfolgten Erfassungen zum Angebot samen- und früchtetragender Gehölze in der Variante CS-E (in der neben Pappelklonen partiell heimische Gehölze mit dem Ziel einer ökologischen Aufwertung angepflanzt wurden) und in den Hecken. Insgesamt wurden in den Hecken die meisten Vogelarten nachgewiesen und die meisten Vögel beobachtet. In den Hecken gelangen sogar mehr Artnachweise und Vogelbeobachtungen (16 Arten, 195 Vogelbeobachtungen) als in allen drei CS-Varianten zusammen (alle CS-Varianten: 13 Arten und 136 Beobachtungen, davon 12 Arten und 116 Beobachtungen in CS-A, 5 Arten und 16 Beobachtungen in CS-E und 3 Arten und 4 Beobachtungen in CS-C). In den Abschnitten der CS-Varianten wurden an einem Großteil (77–95%) der Erfassungstermine keine Vögel nachgewiesen, während in den Hecken an 83% der Termine Vögel beobachtet wurden. Auf Ebene der einzelnen Erfassungstermine wurden in den Hecken an allen Terminen signifikant mehr Arten und Vögel pro Abschnitt beobachtet als in CS-C und CS-E. Hecken und CS-A unterschieden sich hingegen nur an drei von acht Terminen signifikant (Hecken mit mehr Arten und Vogelbeobachtungen). Von den drei CS-Varianten wurden in CS-A zwar die insgesamt meisten Vogelarten und -individuen beobachtet; dennoch bestand an keinem der acht Erfassungstermine ein signifikanter Unterschied zwischen den drei Varianten. Hinsichtlich des Angebotes samen- und früchtetragender Gehölze wurden zwar pro Abschnitt ähnlich viele Gehölzarten in CS-E und Hecken nachgewiesen, in den Hecken trugen jedoch wesentlich mehr Gehölzarten und -individuen auch tatsächlich Samen und Früchte. Das Nahrungsangebot war in den Hecken somit wesentlich größer und diverser. Die Ergebnisse zeigen, dass Hecken im Winter deutlich bedeutsamere (Nahrungs-)Habitate für Vögel darstellen als CS.

Das überraschend schlechte Abschneiden der Variante CS-E ist wohl darauf zurückzuführen, dass die heimischen Gehölze dort zuletzt ein Jahr vor der Untersuchung beerntet wurden und auch ansonsten in kurzen Intervallen (3–6 Jahre) gemeinsam mit den Pappelklonen zurückgeschnitten werden, was das geringe und wenig diverse Angebot samen- und früchtetragender Gehölze trotz der Anpflanzung zahlreicher (potenziell samen- und früchtetragender) heimischer Gehölzarten erklärt. Die heimischen Gehölze in CS-E sollten daher in deutlich größeren Abständen auf den Stock gesetzt werden, damit diese Variante künftig eine größere Bedeutung als Nahrungshabitat für Vögel erlangt. Die eindeutige Präferenz von Vögeln für die Hecken und deren auch noch zum Ende des Erfassungszeitraumes deutlich diverseres und umfangreicheres Nahrungsangebot deuten in Verbindung mit der (aktuell) geringen Nutzung von CS-E darauf hin, dass im untersuchten Landschaftsausschnitt ein ausreichendes Angebot samen- und früchtetragender Gehölze vorhanden war und die Integration der CS und die Anpflanzung heimischer Gehölze in CS-E daher wenig Mehrwert erbrachte. Moderne silvoarable AFS mit CS werden daher vermutlich vor allem in ausgeräumten Agrarlandschaften, in denen es an höherwertigen Gehölzlebensräumen wie Hecken oder Feldgehölzen mangelt, bedeutsam sein. Hier könnte dann die Anpflanzung heimischer Gehölzarten, die Samen und Früchte tragen und für eine Nutzung im Kurzumtrieb geeignet sind (wie Schwarzerlen, Sandbirken oder Ebereschen), oder die Integration samen- und früchtetragender Bäume zur Produktion von Wertholz das Nahrungsangebot und den Strukturreichtum der CS zusätzlich erhöhen.

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